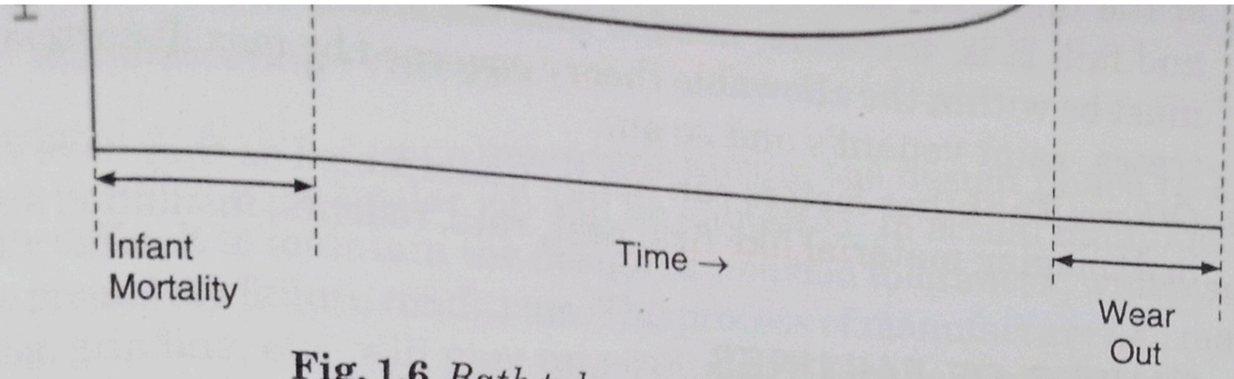

Fig. 1.6. *Bath tub curve and hazard rate*

1.10 FACTORS INFLUENCING FAILURE RATE

The following factors are most important that affects the failures of equipments/systems and therefore should be given due care in the design and manufacturing phase of the equipment:

(*a*) *Quality:* The quality of parts depends on the quality of material used. If the quality of components is higher, lower will be the failure rate and will increase the cost of equipment/system. A poor quality wire for motor binding, poor quality of piston cylinder and piston will lower the performance of engine.

(*b*) *Temperature:* The failure rate of electronic components is highly dependent on the temperature of the component. The failure rate depends on activation energy, (*i.e.*, higher the energy, higher is the failure rate). However; the temperature of components/parts also depends upon the surrounding temperature. The electrical insulation properties of materials change at both high and low temperatures. Corrosion also increases with rise in temperature. Even the wear rate of mechanical component also increases with rise in temperature. Viscosity of the fluids also changes with the change in temperature.

(c) *Environment:* Temperature is one of the examples of environment factors, which affects the failure rate of components. The other environmental factors include, humidity, salt and dust in atmosphere, exposure of frost.

(d) *Material Degradation Phenomena (MDP):* There are various process parameters that are responsible for failure of component(s) viz. nature of process material, vibration, mechanical shock, thermal shock and electromagnetic radiation.

(e) *Corrosion:* The material get corroded in all weather conditions. 5% of yearly production of steel is destroyed by corrosion. The corrosion is severe in sultry, acidic and alkalis conditions. The failure rate of instruments in contact with process fluid is significantly higher than those in contact with the background plan environment. Even the

1.6 MAINTENANCE TERMS AND DEFINITIONS

This section presents some terms and definitions directly or indirectly used in engineering maintenance: [GBTU 2012-13]

- **Maintenance:** All actions appropriate for retaining an item/part/ equipment in, or restoring it to, a given condition.
- **Maintenance engineering:** The activity of equipment/item maintenance that develops concepts, criteria, and technical requirements in conception and acquisition phases to be used and maintained in a current status during the operating phase to assure effective maintenance support of equipment.
- **Preventive maintenance:** All actions carried out on a planned, periodic, and specific schedule to keep an item/equipment in stated working condition through the process of checking and reconditioning. These actions are precautionary steps undertaken to forestall or lower the probability of failures or an unacceptable level of degradation in later service, rather than correcting them after they occur.
- **Corrective maintenance:** The unscheduled maintenance or repair to return items/equipment to a defined state and carried out because maintenance persons or users perceived deficiencies or failures.
- **Predictive maintenance:** The use of modem measurement and signal-processing methods to accurately diagnose item/equipment condition during operation.
- **Maintenance concept:** A statement of the overall concept of the item/ product specification or policy that controls the type of maintenance action to be employed for the item under consideration.
- **Maintenance plan:** A document that outlines the management and technical procedure to be employed to maintain an item; usually describes facilities, tools, schedules, and resources.
- **Reliability:** The probability that an item will perform its stated function satisfactorily for the desired period when used under the specified conditions.
- **Maintainability:** The probability that a failed item will be restored to adequate working condition.
- **Active repair time:** The component of downtime when repair persons are active to effect a repair. [GBTU 2012-13]
- **Mean time to repair (MTTR):** A figure of merit depending on item maintainability equal to the mean item repair time. In the case of exponentially distributed times to repair, MTTR is the reciprocal of the repair rate.
- **Overhaul:** A comprehensive inspection and restoration of an item or a piece of equipment to an acceptable level at a durability time or usage limit.
- **Quality:** The degree to which an item, function, or process satisfies requirements of customer and user.
- **Maintenance person:** An individual who conducts preventive maintenance and responds to a user's service call to a repair facility, and performs corrective maintenance on an item. Also called custom engineer, service person, technician, field engineer, mechanic, repair person, etc.

cleanliness of the fluid will affect the failure rate. Even one environmen factor is enough to cause an early failure but two of these factors ma aggravate the failure rate to a greater extent, example is the presen of salt with humidity, which causes corrosion.

(*f*) *Stress:* In a mechanical system such as beam or strut which are subjecte to stresses, produces corresponding strain greater than the elastic lim of the material, the material is likely to undergo plastic deformatio and fail. It is, therefore, needed that the strain caused in the materia must be within the allowable theory governed by max distortion energ tresca, saint venant's and so on.

(*g*) *Others:* The other factors can not be undermined as they have vital rol in damaging material like fire, pest, rats, rodents, insulation and so on

1.11 CAUSES OF FAILURES

The followings are the major causes of failures, which normally occur i engineering equipment/systems:

1.11.1 Design Deficiencies

All the parameters of field load conditions are very difficult if not impossible t be taken care of and therefore all the requirements are not converted int specifications. All the performance related parameters couldn't be visualize fully during the design phase. Some of the factors considered during design ma not be conductive for the proper functioning of a component and the same ma cause failure. These factors can be identified during the performance testing o the equipment/systems. Such factors contribute towards the design deficiencies however, the same can be incorporated during the redesign phase of the element component. The various reasons for such deficiencies are the following:

(*a*) Lack of advanced design analysis: Advance design may require grea deal of computational and expertise which can not be economical fo many circumstances. The design under many idealization is not realisti to practical conditions. Key ways, Holes, notches, dynamic loading thermal stress and frictional forces, vibrations, etc. are not considere for the simplicity purposes.

(*b*) During the design phase, it is difficult to assess the actual loadin conditions or forces to which a part of element will be subjected to since, the same are designed for optimum working conditions. The bas concepts in design include lightweight and minimum cost or sometime the geometry of the component/element may play an important rol Because of the geometry of the component design deficiencies are ver common.

1.11.2 Material Selection

The right material is one of major concern for failure. In actual practice, it i found that maximum failures are due to improper selection of materials, as th do not fulfill the design requirements. The tests, which are carried on the standa material but in actual manufacturing the same may not be used. The stand

must be checked for its properties with correct sample size and appropriate significance level. Some materials are good either in tension or in compression, but the same may be used where both above conditions do exist. The common example is the beam, which is subjected to tension as well as compression. The imperfection of materials may also cause premature failures because of propagation of cracks in certain areas. Therefore, the selection of proper material for the real working conditions is of paramount importance. Sample testing or non destructive testing must be performed to know the real strength of material or any flaw.

1.11.3 Manufacturing Process

Dimensional analysis is very important during the design phase to know the stresses to which a particular job will be subjected. In actual manufacturing, it is really difficult to maintain the design dimension tolerances, which again will lead to premature failure conditions. The process of manufacture *i.e.*, machining, welding, grinding, etc., will play important role for the desired performance of the component/element. During manufacture of an item by machining the surface temperatures are likely to vary, which will change the surface characteristics of the material. Some undesired marks, indentation, etc., are the potential source of failure of a component due to formation of cracks during use. Even improper heat treatment may cause surface irregularities which in due course of time may lead to premature failure.

During assembly of parts, due to inaccurate/incomplete specifications may cause early failure of components. Misalignment of the parts resulting in bent shafts, bearings seals, etc., may be one of the primary causes of failure of the assembled parts/components.

The improper service conditions will also affect the rate of failures. Through proper checking, inspection and monitoring the failure rate under such working conditions can be minimized. When newly assembled parts are put in service for the first time, due care should be taken for the unexpected working conditions for example, steep rise in temperature or even slight misalignment. A rapid increase in the speed or sudden rise in pressure may lead to severe damage.

The causes of failures can be many but a few of them are given as under:

(*a*) Wear out failures, where failures are due to normal wear and tear of the parts as expected due to use of the equipment/system.

(*b*) Misuse failure, these failures can be the cause of over-stressing the component/part beyond their capabilities, and

(*c*) Inherent weakness failure, these failures are associated during the design and manufacturing of the equipment/system. In other words the broad classification of the failures can be as follows:

1.11.4 Service Failure

In most of the machinery/system the failures experienced are fracture, excessive deformation and surface failures particularly corrosion. These failures are normally time-dependent and can be checked during inspection and maintenance. Sometimes non-destructive techniques (NDT) may be needed to trace the failures without even dismantling the component.

1.11.5 Fatigue

This type of failure occurs when the loading is cyclic in nature and where cracks initiates and grow, which cause failure of the components/parts. Though the fatigue limits are set in advance but the operating conditions may influence an early fatigue failure. In some important equipment fatigue metres are attached for monitoring the condition of the system regularly to avoid accidents.

Basically, fatigue starts with the formation of micro-cracks, which may be due to surface roughness or any other reason and are limited to surface grains only. Due to cyclic loading, these micro-cracks propagate and sometimes lead to fatigue failure of the equipment.

The other reason for fatigue can be stress concentration, which may originate from geometrical configurations; however, their values can be determined to avoid failures. Changes in shape may also lead to stress raisers, which may be deliberate due to design requirement or due to manufacturing defects. The more common stress raisers are notches, de-carbonization corrosion, inclusions, internal stress and clamping devices used during manufacture of products.

Surface fatigue can also occur due to heat treatment and rolling loads particularly in ball bearings. Metallurgical changes have limited effect on fatigue life of products. The principle factors are grain size, microstructure and orientation. The vibration in a system may be the prime cause of fatigue failure.

1.11.6 Excessive Deformation

The components/parts are normally subjected to static, dynamic and fluctuating loads. Static loads may be applied gradually or suddenly. Under gradual loads equilibrium of parts is easy to maintain whereas in case of dynamic or fluctuating loading conditions, the components/parts are required to move, which produces inertia forces. If these inertia forces are not properly balanced, will generate severe vibrations and ultimately deformation of the parts/structure.

1.11.7 Wear

Wear is a common phenomena between two surfaces in contact and will cause surface deterioration in the form of micro-cutting, plastic and elastic deformation, surface fatigue, local heating, oxidation, etc. With the use of lubricants micro-cracks are excessively pressurized which leads to damage of the surface layers.

The wear in actual form can be classified as under:

(*a*) Abrasive wear, which is caused by ploughing or gauging hard particles against the soft working surfaces. It is quite obvious that the softer material will wear out more than the hard material.

(*b*) Scuffing can occur when ideal hydrodynamic lubrication cannot be maintained under sliding conditions. Under these conditions, the lubricant layer formed between the mating surfaces break off.

(*c*) Fatigue wears. This occurs in rolling friction and is caused by fatigue of the surface layers.

(*d*) Molecular wear occurs when two mating surfaces are subjected, to high pressures.

(*e*) Mechanical oxidation wear is caused when the surfaces are exposed to oxidation process in equipment/system.

(*f*) Cavitations can be caused when surface is acted upon by a fluid flow with local hydraulic impacts.

1.11.8 Corrosion

Corrosion mainly occurs when the equipment/system is subjected to humid conditions and it gradually makes the surface weak and can fail after sometime. The corrosion activity normally depends upon the working environment and can be identified as stress corrosion fatigue or cavitations.

The stress corrosion takes place when stresses are applied on the equipment/system when it is placed in humid atmosphere. This takes place in the form of cracks where material is not even subjected to plastic state. Under fluctuating load conditions where components/parts are placed in corrosive atmosphere, the corrosion fatigue takes place. Whereas the cavitations occurs with the collapse of minute vapor bubbles mainly when the equipment is working in a corrosive environment.

1.11.9 Blockage

When fluid flow takes place in any system, it is likely to get blocked due to formation of sludge's in the fluid. This is mainly found in cooling towers and radiators of internal combustion engines. These blockages create excessive pressure on the surface and cause it to fail.

STATISTICS FOR RELIABILITY

that Δn number of specimens have